DATA ACQUISITION SENSORY FRAMEWORK FOR AUTONOMOUS ROBOTS

Adam Ligocki
Doctoral Degree Programme (1), FEEC BUT
E-mail: xligoc01@stud.feec.vutbr.cz

Supervised by: Luděk Žalud
E-mail: zalud@feec.vutbr.cz

Abstract: In this paper there are described the basic hardware idea of complex sensory framework design and construction. This framework will be used to develop high bandwidth data acquisition system in the first phase and lately to use collected data to propose highly antonomous algorithms for field-operating robots. Entire system is divided into four parts. The scalable sensory cluster with highly modular architecture which allows to connect practically arbitrary number of sensing devices, the data acquisition unit, high computational power computer which aggregates all sensor data, preprocess them and storage them in database to provide future access and usage for following applications. The third part is interconnecting network, which provides high bandwidth communication channels to exchange data between sensors and central computer. The last part is battery-based power supply system designed to fulfill 500W energy requirements of entire mobile framework system.

Keywords: Data Acquisition, Camera, LiDAR, IMU, GNSS, Odometry, Data Fusion

1 INTRODUCTION

This paper describes the basic concepts of data acquisition framework which is initial part of the new project of the Robotics and Artificial Inteligence research group of Department of Control and Instrumentation of FEEC BUT .

This first phase of the entire long-term project is aimed to design sensory framework and high bandwidth data acquisition system. This task includes problems like proper sensor selection with wide range of output data types, communication channel that would interconnect sensors with acquisition unit and finaly desing and realization of the acquisition unit.

2 AUTONOMOUS ROBOTS

Robotics and AI research group is long-time focusing on developing robotic systems with high level of autonomy and human independent behavior. Let's mention for example the ATEROS [7] robotic system, which is primarily designed to operate in environments which are dangerous for human beings, like radiation or chemical contaminated surroundings called Urban Search and Rescue (USAR). ATEROS consists of more types of robots to cover different types of mission requirements. In this days this system is succesfully deployed in military sector [5].

To make system even more autonomous there is need to provide to the ATEROS member robots like Orpheus[6] the informations and data acquisition about their surrounding environment that would be used in more complex mission planning algorithms or better environment visualization for operator who is supervising entire mission.

This sensory framework will be primarily used to develope new technical approaches to collect large amount of data and in the second phase this data will be used to develop new algorithms for autonomous robot behavior and data fusion by using wide range of various sensory types.

3 CONCEPT

As shown in Figure 1, system is divided into four separated logical structures. The first cluster contains all sensors which are installed on the framework. Each sensor entity represents the physical sensor (HW) as well as the software driver (SW), which provides communication interface between sensor and data acquisition unit. Sensor list is described more in detail in section 4. The second part of framework is Power Supply block. Because of mobile purpose of this project when framework will be very often installed on mobile robost or platforms, there will be no access to electrical grid so we have to ensure solid battery power supplement.

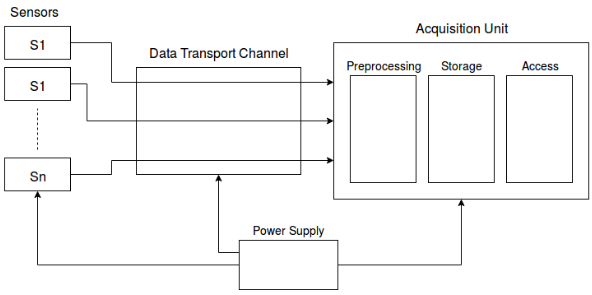

Figure 1: Data acquisition system schematic.

3.1 NETWORK

The network cluster is aiming on data flow and information transition between every single sensor and central acquisition unit. The communication network between endnodes have to provide very high data bandwith because current configuration of all sensors generates nearly 10Gb/s data flow, which could even expand in the future.

Entire communication is deployed on TCP/IP and UDP/IP protocol and physicaly all sensors are connected to network by FTP Patch cable with CAT6 standart and RJ45 end cap.

As a central point of this block the configurable switch DGS-1510-20 has been choosen. It has sixteen common 1Gb/s ports which should cover all in the future installed sensors and two 10Gb/s SPF+ ports, which will be used as a main input channel into data acquisition unit where all data flow will be agregated into single link. For short distances the 10Gb/s channel will be realised by cooper twisted pair. For longer distance communication it could be replaced by the optical interface. Internal data bandwidth of mentioned switch is 76Gb/s which is far larger than we currently expect.

3.2 ACQUISITION UNIT

The acquisition unit is the core of entire sensory framework. It collects all sensor data and process them in the way that other systems can use this collected data for their specific task.

In our case acquisition unit is common PC architeture computer, but during configuration specification there were very strong requirements for high computational power and strong paralelism so the high number of concurency tasks and data processing processes could operate at the same time. For this purpose the high-end CPU and GPU have been choosen, specifically the 32-thread AMD RYZEN Threadripper 1950X CPU at 4GHz core frequency and 64 PCIe lines and NVidia GTX 1080Ti graphic card with 3584 stream processors, Cuda technology and 11GB of memory.

Configuration above provides very high computation power but also this hardware has very high power consumption (talking about 400W in peak) which is quite chellenging to fill them up with battery powered system.

3.3 Power Source

Sumarizing all the elements tohether, the total power consumption is approximetly about 500W in peak. As a solution the Li-pol batery concept has beep proposed.

There has been proposed original batery packag. It contains 30 Li-pol cells, which are organised in five branches by six cells in a series. Every cell has 3500mAh capacity and is able to provide 2C discharge current. In five branchech for single batery pack it gives 22.8V by 35A which is nearly 798W power in peak. Also total capacity of this single battery pack is 399Wh so it is able to power entire sensory framework for nearly 50 minutes.

4 SENSORS

4.1 Cameras

Cameras are the backbone of entire sensory grid. For our solution the layout of 5 cameras has beed proposed. Two devices are frontal, so there is possibility to use precise stereo vision in front of the robot.

The main feature of the camera sensor cluster is that all cameras are proposed in a way that they create 360deg field of view (FoV). This is very useful bacause it gives us large amount of data about surrounding environment and in the future there will be a possibility to develop very sophisticated algorithms based on all-direction vision.

The layout of all cameras is shown in Figure 2. The front cameras have appproximitly 70 deg FoV and the two lateral cameras and the rear one are proposed to have about 120deg FoV so the entire system will have full 360 deg vision information. For this puprpose it will be nececary to implement camera image registration tool which will be able to connect all five images into single panoramic mosaic.

4.2 LIDARs

LiDAR is laser based time of flight (ToF) sensor which measures distance to the obsteacle by raycasting laser beams and measuring time in which the beam returns.

For this project two Velodyne HDl-32e sensors had been choosen. Every sensor has 360 deg Fov with 0.2 deg resolution and 41.33 deg of vertical FoV with 1.33 deg resolution. Every sensor has a GNSS time synchronisation, so the output data has us precision time stamp synchronisation.

Every LiDAR steams about 30Mb/s which requires 100Mb/s physical link.

It is also very important that Velodyne rotates ten times per second so the entire 360 deg measurement takes 100ms. If this solution will be deployed on robots or cars that are moving several meters per second, the large translation distorcion large could appear and it has to be compensated.

4.3 IMU

Inertial unit is used to precise rotation estimation of the entire framework (roll, pitch, yaw angles) as well as short therm dynamic acceleration data. This data mentioned above will help to cempensate measurement error like for example camera to ground projection, or LiDAR's point cloud preprocessing. For this project Xsens MTi-G-710 unit has been choset. I provides output data with 2kHz frequency and precision of 0.2 deg/s for gyro and 5mg for acceleromenter.

4.4 GNSS

To extimate absolute robot position there will be installed Trimble BC982 GNSS receiver with a pair of differencial antennas. This device is compatibile with GPS L5, GLONASS L3, and Galileo signals. Durign good conditions this device provides 5cm RMS precision.

With two receiver antennas located one meter from each other it is also possible to estimate robot asimut with few degrees precision. This information can be used for long-term gyro yaw angle drift compensation.

4.5 ODOMETRY

Odometry is proposed in a way that external data source will be sending data about wheels rotation into acquisition unit and central will be calculating the motion model in realtime [4]. In this case we can think about odometry as a abstract sensor, which will be implemented as a wrapper above physical encoders.

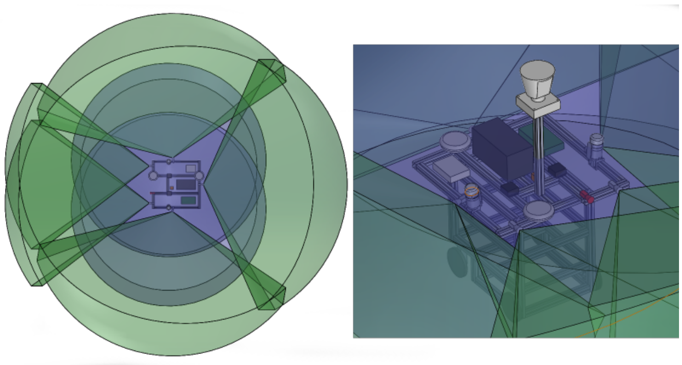

Figure 2: Floor plan and real deployment visualization of proposed sensory framework hardware. Green: Proposed FoV of cameras. The edge of frame is one meter long.

5 RELATED WORKS

The main inspiration for this framework comes form [2]. This benchmark dataset represents the current state-of-art database of self-driving-car oriented learning data. There are benchmarks to test odometry, camera and LiDAR based object detection, tracking and clasification, etc. This project is aiming to be able to create large scale learning data for autonomous robots, like [1] or [3].

6 CONCLUSION

During this project the hardware concept of complex sensory framework has been theoreticaly proposed and the prototype has been physicly realised. (shown at Figure <image>). The main frame is made out of dural profile to ensure wigh durabiliti and low weight. The most of the devices are mounted to the schasee by 3D printed PLA costruction elements, so entire framework is very easly disassembled. Network TCP/UDP communication is based on configurable switch withc 1 and 10Gb/s ports and with 76Gb/s maximum bandwidth capacity. All connection are realizeb by RF45 patch cables of CAT6 standard. The acquisition unit is highly paralelized PC computer platform with

32 thread 4GHz AMD procesor and NVidia 1080Ti. The whole hardware configuration is powered by two 400Wh Li-pol battery packs.

Final product has been mounted on experimental robotic platform and wide range of power consuption and network connectivity tests have been performed, all with positive results.

In the future this plaftorm will be used to generate large scale learning and validation datasets to develop new authonomous algorithms for wide range of robotics puposes.

Figure 3: First version of real deployment of sensory framework.

ACKNOWLEDGEMENT

The completion of this paper was made possible by the grant No. FEKT-S-17-4234 - „Industry 4.0 in automation and cybernetics" financially supported by the Internal science fund of Brno University of Technology.

REFERENCES

[1] M. Cordts, M. Enzweiler, R. Benenson, S. Ramos, T. Scharw, U. Franke, S. Roth, D. a. G. R, T. U. Darmstadt, M. P. I. Informatics, and T. U. Dresden. The Cityscapes Dataset. *Cvpr*, 2015.

[2] A. Geiger, P. Lenz, C. Stiller, and R. Urtasun. Vision meets robotics: The KITTI dataset. *International Journal of Robotics Research*, 32(11):1231–1237, 2013.

[3] W. Maddern, G. Pascoe, C. Linegar, and P. Newman. 1 year, 1000 km: The Oxford RobotCar dataset. *International Journal of Robotics Research*, 36(1):3–15, 2017.

[4] S. Thrun, W. Burgard, and D. Fox. Probabilistic robotics (intelligent robotics and autonomous agents series). *Intelligent robotics and autonomous agents, The MIT* . . . , 45:52, 2005.

[5] L. Zalud. Orpheus - Universal reconnaissance teleoperated robot. In Nardi, D and Riedmiller, M and Sammut, C and SantosVictor, J, editor, *ROBOCUP 2004: ROBOT SOCCER WORLD CUP VIII*, volume 3276 of *LECTURE NOTES IN COMPUTER SCIENCE*, pages 491–498, HEIDELBERGER PLATZ 3, D-14197 BERLIN, GERMANY, 2005. SPRINGER-VERLAG BERLIN.

[6] L. Zalud. Orpheus - Universal reconnaissance teleoperated robot. In Nardi, D and Riedmiller, M and Sammut, C and SantosVictor, J, editor, *ROBOCUP 2004: ROBOT SOCCER WORLD CUP VIII*, volume 3276 of *LECTURE NOTES IN COMPUTER SCIENCE*, pages 491–498, HEIDELBERGER PLATZ 3, D-14197 BERLIN, GERMANY, 2005. SPRINGER-VERLAG BERLIN.

[7] L. Zalud. ARGOS - System for heterogeneous mobile robot teleoperation. In *IEEE International Conference on Intelligent Robots and Systems*, pages 211–216, 2006.